PCT/SE2003/001091
21-09-2004
10/518430
DT01 Rec'd PCT/PTC 20 DEC 2004

CLAIMS

1. A method to locate a fault from one end of a section of a power line (A-B) by means of measurements of current, voltage and angles between the phases at a first (A) end of said section,
characterised by
- calculating symmetrical components of currents for said current and voltage measurement at said first end (A),
- calculating a value of impedance for an extra link (45, 55) between the terminals (A,B) with the impedance for the positive sequence equal to:
($\underline{Z}_{1LB\&AB} = \dfrac{\underline{Z}_{1LB}\underline{Z}_{1AB}}{\underline{Z}_{1LB}+\underline{Z}_{1AB}}$) where:
$\underline{Z}_{1AB}$ = impedance for the positive sequence of the extra link,
$\underline{Z}_{1LA}$ = positive-sequence impedance of the healthy line,
- determining a compensation for the shunt capacitance with the aid of an equation (22) of the form:
$B_2^{comp\_1}(d_{comp\_1})^2 + B_1^{comp\_1}d_{comp\_1} + B_0^{comp\_1} = 0$ where:
$B_2^{comp\_1} = A_{2\_Re}^{comp\_1}A_{00\_Im}^{comp\_1} - A_{2\_Im}^{comp\_1}A_{00\_Re}^{comp\_1}$
$B_1^{comp\_1} = A_{1\_Re}^{comp\_1}A_{00\_Im}^{comp\_1} - A_{1\_Im}^{comp\_1}A_{00\_Re}^{comp\_1}$
$B_0^{comp\_1} = A_{0\_Re}^{comp\_1}A_{00\_Im}^{comp\_1} - A_{0\_Im}^{comp\_1}A_{00\_Re}^{comp\_1}$
- determining the zero-sequence current from the healthy line of a section of parallel power lines,
- calculating a distance to a falt for the parallel line section,
- calculating the distance (d) to the fault (F) from said first end (2) using a quadratic equation (26) of the form:
$B_2d^2 + B_1d + B_0 = 0$ where:
$B_2 = A_{2\_Re}A_{00\_Im} - A_{2\_Im}A_{00\_Re}$
$B_1 = A_{1\_Re}A_{00\_Im} - A_{1\_Im}A_{00\_Re}$
$B_0 = A_{0\_Re}A_{00\_Im} - A_{0\_Im}A_{00\_Re}$

2. A method according to claim 1, **characterised** by calculating the distance (d) to the fault using an equation of the form:

$$\underline{K}_1\underline{Z}_{1L}d^2+(\underline{L}_1\underline{Z}_{1L}-\underline{K}_1\underline{Z}_{AA\_p})d-\underline{L}_1\underline{Z}_{AA\_p}+R_F\underline{M}_1\frac{(\underline{a}_{F1}\Delta\underline{I}_{AA1}+\underline{a}_{F2}\underline{I}_{AA2})}{\underline{I}_{AA\_p}}=0 \qquad (8)$$

where:

$\underline{Z}_{AA\_p}=\frac{\underline{V}_{AA\_p}}{\underline{I}_{AA\_p}}$ - calculated fault loop impedance.

3. A method according to any of claim 1 or 2, **characterised** by calculating the distance (d) to the fault using an equation of the form:

$$\underline{A}_2d^2+\underline{A}_1d+\underline{A}_0+\underline{A}_{00}R_F=0$$

where:

$\underline{A}_2=A_{2\_\mathrm{Re}}+\mathrm{j}A_{2\_\mathrm{Im}}=\underline{K}_1\underline{Z}_{1LA}$

$\underline{A}_1=A_{1\_\mathrm{Re}}+\mathrm{j}A_{1\_\mathrm{Im}}=\underline{L}_1\underline{Z}_{1LA}-\underline{K}_1\underline{Z}_{AA\_p}$

$\underline{A}_0=A_{0\_\mathrm{Re}}+\mathrm{j}A_{0\_\mathrm{Im}}=-\underline{L}_1\underline{Z}_{AA\_p}$

$A_{00\_\mathrm{Re}}+\mathrm{j}A_{00\_\mathrm{Im}}=\frac{\underline{M}_1(\underline{a}_{F1}\Delta\underline{I}_{AA1}+\underline{a}_{F2}\underline{I}_{AA2})}{\underline{I}_{AA\_p}}$

$\underline{Z}_{AA\_p}=\frac{\underline{V}_{AA\_p}}{\underline{I}_{AA\_p}}$ = calculated fault loop impedance

$\underline{K}_1$, $\underline{L}_1$, $\underline{M}_1$ = coefficients gathered in TABLE 3.

4. A method according to one or more of the preceding claims, **characterised** by
- determining source impedance at said first end as a representative value, and
- determining a value for source impedance at said second end as a representative value.

5. A method according to one or more of the preceding claims, **characterised** by calculating symmetrical components of currents for said current and voltage measured at said first end by:
- inputting instantaneous phase voltages (30a),
- filtering (33a) the values to determine the phasors, and
- calculating (34a) phasors of symmetrical components of voltages.

6. A method according to one or more of the preceding claims, **characterised** by calculating symmetrical components of currents for said current and voltage measured at said first end by:

- inputting instantaneous phase currents and instantaneous zero-sequence current from a healthy line (30b),
- filtering (33b) the values to determine the phasors, and
- calculating (34b) phasors of symmetrical components of currents.

7. A method according to one or more of the preceding claims, **characterised** by determining a compensation for shunt capacitance by means of an equation of the form:

$$\underline{A}_2^{comp\_1}(d_{comp\_1})^2 + \underline{A}_1^{comp\_1} d_{comp\_1} + \underline{A}_0^{comp\_1} + \underline{A}_{00}^{comp\_1} R_F = 0 \qquad (21a)$$

where:

$$\underline{A}_2^{comp\_1} = A_{2\_Re}^{comp\_1} + jA_{2\_Im}^{comp\_1} = \underline{K}_1 \underline{Z}_{1L}^{long}$$

$$\underline{A}_1^{comp\_1} = A_{1\_Re}^{comp\_1} + jA_{1\_Im}^{comp\_1} = \underline{L}_1 \underline{Z}_{1L}^{long} - \underline{K}_1 \underline{Z}_{A\_p}^{comp\_1}$$

$$\underline{A}_0^{comp\_1} = A_{0\_Re}^{comp\_1} + jA_{0\_Im}^{comp\_1} = -\underline{L}_1 \underline{Z}_{A\_p}^{comp\_1}$$

$$\underline{A}_{00}^{comp\_1} = A_{00\_Re}^{comp\_1} + jA_{00\_Im}^{comp\_1} = \frac{\underline{M}_1(\underline{a}_{F1}\Delta\underline{I}_{AA1} + \underline{a}_{F2}\underline{I}_{AA2})}{\underline{I}_{A\_p}^{comp\_1}}$$

$\underline{Z}_{A\_p}^{comp\_1} = \frac{\underline{V}_{A\_p}}{\underline{I}_{A\_p}^{comp\_1}}$ - fault loop impedance calculated from:

$\underline{V}_{A\_p}$ - original (uncompensated) fault loop voltage,

$\underline{I}_{A\_p}^{comp\_1} = \underline{a}_1 \underline{I}_{A1\_comp\_1} + \underline{a}_2 \underline{I}_{A2\_comp\_1} + \underline{a}_0 \underline{I}_{A0\_comp\_1}$ - fault loop current composed of the positive (12), negative (16) and zero (17) sequence currents obtained after deducing the respective capacitive currents from the original currents, and

$\underline{K}_1$, $\underline{L}_1$, $\underline{M}_1$ = coefficients gathered in TABLE 3.

8. A method according to one or more of the preceding claims, **characterised** by measuring the source impedance $\underline{Z}_{1sA}$ at said first end A.

9. A method according to one or more of the preceding claims, **characterised** by
-measuring the source impedance $\underline{Z}_{1sB}$ at said second end B,

-sending a communication of the measured value of source impedance $\underline{Z}_{1sB}$ at said second end B to a fault locator at said first end A.

10. A method according to one or more of the preceding claims, **characterised** by determining the distance to a single phase to ground fault without measurements from an operating healthy parallel line by means of complex coefficients $\underline{P}_0$ according to a formula of the form:

$$\underline{P}_0 = \frac{\underline{Z}_{0LB} - \underline{Z}_{0m}}{\underline{Z}_{0LA} - \underline{Z}_{0m}}$$

and $\underline{K}_1$, $\underline{L}_1$, $\underline{M}_1$ according to

$$\underline{K}_1 = -\underline{Z}_{1LA}(\underline{Z}_{1sA} + \underline{Z}_{1sB} + \underline{Z}_{1LB})$$

$$\underline{L}_1 = -\underline{K}_1 + \underline{Z}_{1LB}\underline{Z}_{1sB}$$

$$\underline{M}_1 = \underline{Z}_{1LA}\underline{Z}_{1LB} + \underline{Z}_{1LA}(\underline{Z}_{1sA} + \underline{Z}_{1sB}) + \underline{Z}_{1LB}(\underline{Z}_{1sA} + \underline{Z}_{1sB})$$

11. A method according to one or more of the preceding claims, **characterised** by determining the distance to a single phase to ground fault without measurements from switched off and grounded parallel line by means of complex coefficients $\underline{P}_0$ according to

$$\underline{P}_0 = -\frac{\underline{Z}_{0LB}}{\underline{Z}_{0m}}$$

and $\underline{K}_1$, $\underline{L}_1$, $\underline{M}_1$ according to

$$\underline{K}_1 = -\underline{Z}_{1LA}$$

$$\underline{L}_1 = \underline{Z}_{1LA} + \underline{Z}_{1sB}$$

$$\underline{M}_1 = \underline{Z}_{1sA} + \underline{Z}_{1sA} + \underline{Z}_{1LA}$$

12. A method according to one or more of the preceding claims, **characterised** by determining the distance to a single ground fault using a first order formula (27a,b,c) of the form:

$$d = \frac{imag\{\underline{V}_{AA\_p}[3(\underline{I}_{AA0} - \underline{P}_0\underline{I}_{AB0})]^*\}}{imag\{(\underline{Z}_{1LA}\underline{I}_{AA\_p})[3(\underline{I}_{AA0} - \underline{P}_0\underline{I}_{AB0})]^*\}}$$

13. A method according to one or more of the preceding claims, **characterised** by determining the distance to a phase-to-phase ground fault using pre-fault measurements and a first order formula (28a,b,c) of the form:

$$d = \frac{imag\{\underline{V}_{AA\_p}[\underline{W}(\underline{I}_{AA0} - \underline{P}_0 \underline{I}_{AB0})]^*\}}{imag\{(\underline{Z}_{1LA}\underline{I}_{AA\_p})[\underline{W}(\underline{I}_{AA0} - \underline{P}_0 \underline{I}_{AB0})]^*\}}$$

14. A method according to one or more of the preceding claims, **characterised** by determining the distance to a phase-to-phase ground fault avoiding pre-fault measurements and using a first order formula (29a,b,c) of the form:

$$d = \frac{imag[(\underline{V}_a + \underline{V}_b)(\underline{I}_{AA0} - \underline{P}_0 \underline{I}_{AB0})^*]}{imag[\underline{Z}_{1LA}(\underline{I}_a + \underline{I}_b + 2\underline{k}_0 \underline{I}_{AA0} + 2\underline{k}_{0m} \underline{I}_{AB0})(\underline{I}_{AA0} - \underline{P}_0 \underline{I}_{AB0})^*]}$$

15. A device for locating a fault from one end of a section of a power line (A-B) having means for receiving and storing measurements of current, voltage and angles between the phases at one first end (A), means for receiving and storing a detection of a fault condition between said first and second ends (A,B), **characterised** by:
- means for calculating symmetrical components of currents for said current and voltage measured at said first end (A),
- means for calculating a value of impedance for an extra link (45, 55) between the terminals (A,B),
- means for determining a compensation for shunt capacitance,
- means for determining the zero-sequence current from the healthy line of a section of parallel power lines,
- means for calculating a distance to a fault for the parallel line section,
- means for calculating a distance (d) from said first end (2) to the fault (F).

16. A device according to claim 15, **characterised** by comprising:
- means for determining a value for source impedance at said first end,

PCT/SE2003/001091
21-09-2004
10/518430

- means for determining a value for source impedance at said second end.

DT01 Rec'd PCT/PTC 20 DEC 2004

17. A device according to one or more of claim 15 or 16, **characterised** by comprising:
- means for receiving a measurement of source impedance at said first end A.

18. A device according to one or more of claims 15-17, **characterised** by comprising:
- means for receiving a measurement of source impedance made at said second end B.

19. A device according to one or more of claims 15-17, **characterised** by comprising means to receive a measured value (9) for remote source impedance at said second end (B) communicated by means of a communication channel (60).

20. Use of a fault locator device according to any of claims 15-19, by a human operator to supervise a function in an electrical power system.

21. Use of a fault locator device according to any of claims 15-20, by means of a process running on one or more computers to supervise and/or control a function in an electrical power system.

22. Use of a fault locator device according to any of claims 15-21, to locate a distance to a fault in a power transmission or distribution system.

23. Use of a device according to any of claims 15-22, for locating a fault on parallel power lines.

24. A computer program comprising computer code means and/or software code portions for making a computer or processor perform any of the steps of claims 1-14.

PCT/SE2003/001091
21-09-2004

25. A computer program product according to claim 24 comprised on one or more computer readable media.